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nious plan of Barrett, which is shown to be capable of improvement and extension. Parts of the excellent work of the late Mr. David Jones, 'Tables of Life Annuities,' published under the care and suggestion of the Society for the Diffusion of Useful Knowledge, founded on those ideas of Barrett, are by the author here improved and extended so as to give methods easier for common purposes, and capable of extension to almost all difficulties which are likely to occur in the calculation of the value of property.

## II. "Investigations of the Specific Heat of Solid and Liquid Bodies."

By HERMANN KOPP, Ph.D. Communicated by T. GRAHAM, Esq., Master of the Mint. Received April 16, 1864.

### (Abstract.)

In the first part the author discusses the earlier investigations on the specific heat of solid bodies, and on the relations of this property to their atomic weight and composition. In this historical report he gives a complete analysis of the various opinions published on the subject.

In the second part the author describes the method he has used for determining the specific heat of solid bodies. This method is based on the method of mixtures. The substance investigated is placed in a glass tube, together with some liquid which does not dissolve it, and the tube is heated in a mercury bath, and then rapidly immersed in a calorimeter containing water. Equalization of temperature takes place rapidly, through the intervention of the liquid in the tube. The thermal effect (increase of temperature in the water of the calorimeter) is determined. Preliminary experiments give the means of allowing for the thermal effect due to the glass and to the liquid in it, and of thereby obtaining the thermal effect produced by the solid substance. The author gives a complete description of the apparatus and of the mode of using it, and also of the means of determining the ancillary magnitudes which require to be taken into account. The entire method is very simple, and it brings the determination of specific heat out of the restricted sphere of the physical cabinet, with its complicated apparatus, within reach of the ordinary appliances of the chemical laboratory. It is also applicable to small quantities, and to such substances as cannot bear a high temperature. The author discusses the possible deficiencies as well as the advantages of this method as compared with those of Neumann and of Regnault.

In the third part the author gives his determinations of a very great number of solid bodies. The specific heat of many of them had been determined by Neumann, or by Regnault; and the almost universal agreement of the numbers found by their methods and by his own proved the comparability of his results with those of other physicists. Where there is a considerable difference, the cause is discussed. By far the greatest

number of the author's experiments are on substances whose specific heat had not been previously determined; they extend to all the more important classes of inorganic compounds, and to a great number of organic compounds.

In the fourth part the author gives a synopsis of the materials at present available and trustworthy for considering the relations between specific heat and atomic weight or composition. That is, he gives for solid bodies of known composition the atomic formula, the atomic weight, the more trustworthy determinations of specific heat, and (corresponding to these) the atomic heats, or products of the specific heats and the atomic weights.

The relations between the atomic heat and the atomic weight or the composition are discussed in the fifth part.

A discussion whether the specific heat of a body varies materially with its different physical conditions forms an introduction to this part. The influence which change of temperature of solid bodies exerts on the specific heat is considered. This difference is inconsiderable, as is also the difference of specific heats found for the same substance, according as it is hammered or annealed, hard or soft. With dimorphous varieties of the same substance, even where the specific gravity is different, the same specific heat is found in most cases. Great difference had been supposed to exist in the specific heat of a substance, according as it was crystalline or amorphous. The author shows that, for a great number of substances, there is no such difference, and that in other cases the apparent differences depend on inaccurate determinations of the specific heat. He shows that three sources of error more especially may give too great a specific heat for a substance, or for one of its various modifications:—

1. When the substance is heated to a temperature at which it begins to soften, and thus to absorb part of its latent heat of fusion.
2. If the substance is heated to a temperature at which it begins to pass into another modification, and this change, with its accompanying development of heat, is continued in the calorimeter.
3. If the substance investigated is porous, and (as was the case in the earlier methods) is directly immersed in the liquid of the calorimeter, in which case the development of heat which accompanies the moistening of porous substances comes into play.

The author arrives at the following result:—From what is at present known with certainty, one and the same body may exhibit small differences with certain physical conditions (temperature, or different degrees of density or porosity); but these differences are never so great as to furnish an explanation of cases in which a body markedly deviates from a regularity which might perhaps have been expected for it—always assuming that the determination of the specific heat, according to which the body in question forms an exception to the regularity, is trustworthy and free from foreign elements.

The author then discusses the applicability of Dulong and Petit's law.

The atomic heats of many elements\* are, in accordance with this law, approximately equal; they vary between 6 and 6·8, the average being about 6·4. The explanations attempted why this law only approximately holds good, he considers inadequate. In any case there are individual elements which do not obey this law. The atomic heat of phosphorus, for instance, as deduced from direct determinations of its specific heat in the solid state, is considerably smaller (about 5·4); and still more so are those of silicium (about 4), of boron (about 2·7), and of carbon (1·8 for diamond).

A regularity, to which attention has been already drawn, is, that the quotient obtained by dividing the atomic heat of a compound by the number of elementary atoms in one molecule, is approximately equal to 6·4; equal, that is, to the atomic heat of an element according to Dulong and Petit's law. Thus the atomic heat of the chlorides  $RCl$  and  $RCl_2$  has been found to be 12·8 on the average, and of the chlorides  $RCl_2 = 18·5$ . Now  $\frac{12·8}{2} = 6·4$ , and  $\frac{18·5}{3} = 6·2$ . The same regularity is met with in metallic bromides, iodides, and arsenides; and, according to the author's determinations, it is even found in the case of compounds which contain as many as seven, and even of nine elementary atoms. The atomic heat of  $Zn K_2 Cl_4$  is 43·4, and that of  $Pt K_2 Cl_6$  is 55·2; now  $\frac{43·4}{7} = 6·2$  and  $\frac{55·2}{9} = 6·1$ . But the author shows at the same time that this regularity is far from being general. For the oxides of the metals the quotient is less than six, and is smaller the greater the number of atoms of oxygen in the oxide. (From the average determinations of the atomic heats, it is for the metallic oxides  $RO_1 = \frac{11·1}{2} = 5·6$ ; for the oxides  $R_2O_3$  and  $R_2O_3 = \frac{27·2}{5} = 5·4$ ; for the oxides  $RO_2 = \frac{13·7}{3} = 4·6$ .) The quotient is still smaller for compounds which contain boron as well as oxygen (for instance, it is  $\frac{16·8}{4} = 4·2$  for the borates,  $RB_2O_3$ ; it is  $\frac{16·6}{5} = 3·3$  for boracic acid,  $B_2O_3$ ), or which contain silicium (for silicic acid,  $SiO_2$ , it is  $\frac{11·3}{3} = 3·8$ ), or hydrogen (for ice,  $H_2O$ , it is  $\frac{8·6}{3} = 2·9$ ), or, finally, which contain carbon and hydrogen as well as oxygen (for succinic acid,  $C_4H_6O_4$ , for instance, it is  $\frac{36·9}{14} = 2·6$ ). It may be stated in a few words, in what cases this quotient approximates to the atomic heat of most of the elements, and in what

\* In accordance with recent assumptions for the atomic weights,  $H=1$ ;  $Cl=35·5$ ;  $O=16$ ;  $S=32$ ;  $B=10·9$ ;  $C=12$ ;  $Si=28$ .  $R$  stands for a monequivalent atom, *e.g.*  $As=75$ ;  $Na=23$ ;  $K=39·1$ ;  $Ag=100$ ;  $R$  signifies a polyequivalent atom, *e.g.*  $Ca=40$ ;  $Pb=207$ ;  $Fe=56$ ;  $Co=63·4$ ;  $Cr=52·2$ ;  $Pt=184$ , &c.

cases it is less. It is near 6·4 in the case of those compounds which only contain elements whose atomic heats, in accordance with Dulong and Petit's law, are themselves approximately = 6·4. It is less in those compounds containing elements which, as exceptions to Dulong and Petit's law, have a considerably smaller atomic heat than 6·4, and which are found to be exceptions, either directly, by determinations of their specific heat in the solid state, or indirectly, by the method to be subsequently described.

After Dulong and Petit had propounded their law, Neumann showed that a similar regularity existed in the case of compounds, that is, that the atomic heats of analogous compounds are approximately equal. Regnault, as is known, has confirmed Dulong and Petit's, as well as Neumann's law, to a considerably greater extent, and for a larger number of compounds, than had been previously done. And Regnault's researches have more especially shown that the elementary atoms, now regarded as monoequivalent, are, as regards the atomic heat of their compounds, comparable with the elementary atoms which are to be considered as polyequivalent. Thus, as regards atomic heat, arsenious acid,  $\text{As}_2\text{O}_3$ , and sesquioxide of iron,  $\text{Fe}_2\text{O}_3$ , or chloride of silver and subchloride of copper,  $\text{CuCl}$ , may be classed together. Of the applicability of Neumann's law, as hitherto investigated and found in the case of chemically analogous compounds, the author's experimental determinations have furnished a number of new examples. But more interest is presented by his results in reference to the applicability of this law to compounds to which it had not hitherto been supposed to apply.

In comparing compounds as regards their atomic heat, their chemical character has been taken into account, as represented by the formulæ hitherto adopted. Sulphates and chromates, for instance, were looked upon as comparable, but they would not have been classed with perchlorates, or with permanganates. According to more recent assumptions for the atomic weights of the elements, the following salts have analogous formulæ, and the adjoined atomic heats have been determined :—

Chromate of lead . . . . .	$\text{Pb Cr O}_4$	29·0
Sulphate of lead . . . . .	$\text{Pb S O}_4$	25·8
Permanganate of potass . . . . .	$\text{K Mn O}_4$	28·3
Perchlorate of potass . . . . .	$\text{K Cl O}_4$	26·3

The atomic heats of carbonates,  $\text{R C O}_3$ , of silicates,  $\text{R Si O}_3$ , of metaphosphates,  $\text{R P O}_3$ , of nitrates,  $\text{R N O}_3$ , are also very near.

But not even a common chemical behaviour, such as the bodies in this group possess—that is, a common haloid character—is necessary in order that compounds of analogous atomic composition shall show the same atomic heat. No one would think of considering magnetic oxide of iron as analogous to chromate of potass; and yet both have the same atomic structure, and determinations of their specific heat have given approximately the same atomic heat for both.

Magnetic oxide of iron . . . . .	$\text{Fe}_3\text{O}_4$	37·7
Chromate of potass . . . . .	$\text{K}_2\text{Cr O}$	36·4

And it is not less surprising that arseniate of potass,  $\text{K As O}_3$ , and chlorate of potass have the same atomic heat as sesquioxide of iron,  $\text{Fe}_2 \text{O}_3$ , or arsenious acid,  $\text{As}_2 \text{O}_3$ : with very different characters these compounds have approximately equal atomic heat.

But comparability of chemical compounds, as regards the atomic heat, is not limited to the cases in which, as far as can be judged, the individual atoms have analogous construction. We do not regard the atom of binoxide of tin or of titanio acid as analogous in construction to the atom of tungstate of lime or of chromate of lead; nor to nitrate of baryta, or metaphosphate of lime. But if the formulæ of those binoxides are doubled or tripled, they may be compared with these salts, and their atomic heats are then approximately equal, as is the case for compounds of analogous chemical character. The atomic heats are for—

Binoxide of tin	..... $2 \text{ Sn O}_2 = \text{Sn}_2 \text{O}_4$	27·6
Titanic acid	..... $2 \text{ Ti O}_2 = \text{Ti}_2 \text{O}_4$	27·3
Tungstate of lime	..... $\text{Ca W O}_4$	27·9
Chromate of lead	..... $\text{Pb Cr O}_4$	29·0
Permanganate of potass	..... $\text{K Mn O}_4$	28·3
Perchlorate of potass	..... $\text{K Cl O}_4$	26·3
Binoxide of tin	..... $3 \text{ Sn O}_2 = \text{Sn}_3 \text{O}_6$	41·4
Titanic acid	..... $3 \text{ Ti O}_2 = \text{Ti}_3 \text{O}_6$	41·0
Nitrate of baryta	..... $\text{Ba N}_2 \text{O}_6$	38·9
Metaphosphate of lime	..... $\text{Ca P}_2 \text{O}_6$	39·4

These results seem to give to Neumann's law a validity far beyond the limits to which it had hitherto been considered to apply. But, on the other hand, the author's comparisons go to show that neither Neumann's nor Dulong and Petit's law is universally valid.

Neumann's law is only approximate, as is well known. For such analogous compounds as, from what we know at present, are quite comparable and, in accordance with this law, ought to have equal atomic heats, Regnault found the atomic heats differing from each other by  $\frac{1}{10}$  to  $\frac{1}{9}$ . In a few such cases there are even greater differences in the atomic heats, for which an adequate explanation is still wanting.

But there are other differences in the atomic heats of some compounds which might have been expected to have equality of atomic heat in accordance with Neumann's law—differences which occur with regularity, and for which an explanation is possible. Certain elements impress upon all their compounds the common character that their atomic heats are smaller than those of analogous compounds of other elements. This is the case, for instance, with the compounds of boron: the atomic heat of boracic acid is much less than that of the metallic oxides  $\text{R}_2 \text{O}_3$  and  $\text{R}_2 \text{O}_3$ ; the atomic heat of the borates  $\text{R B O}_2$  is much less than that of the oxides  $\text{R}_2 \text{O}_3 = (2 \text{ R O})$ ; and the atomic heat of borate of lead,  $\text{Pb B}_2 \text{O}_4$ , is far less than that of magnetic oxide of iron,  $\text{Fe}_3 \text{O}_4$ . The same is the case with compounds of carbon, if the alkaline carbonates,  $\text{R}_2 \text{C O}_3$ , are compared with the metallic oxides  $\text{R}_2 \text{O}_3 = (3 \text{ R O})$ , or the carbonates  $\text{R C O}_3$ , with the metallic oxides  $\text{R}_2 \text{O}_3$  and

$R_2 O_3$ . It is seen that the compounds of those elements which, in the free state, have themselves a smaller atomic heat than most other elements, are characterized by a smaller atomic heat.

This leads the author to discuss whether it is to be assumed that the elements enter into compounds with the atomic heats which they have in the free state. This assumption is only admissible provided it can be proved that the atomic heat of a compound depends simply on its empirical formula, and not on the chemical character or rational constitution. Much of what has previously been said favours this view of the case. It is also supported by the fact, which the author proves, that similar chemical character in analogous compounds, and even isomorphism, do *not* presuppose equality in the atomic heats, if in one compound an atomic group (a compound radical) stands in the place of an elementary atom of another: for instance, the atomic heat of cyanogen compounds is considerably greater than those of the corresponding chlorine compounds, and those of ammonium materially greater than those of the corresponding potassium compounds. A further support for that assumption is found in the fact that, regardless of the chemical character, the atomic heat of complex compounds is found to be the sum of the atomic heats of simpler atomic groups, the addition of which gives the formulæ of those more complex compounds. A few cases selected from the comparisons of the author may explain this. The atomic heats have been found,—

For the oxides . . . . .	$R O$	11.1
For binoxide of tin . . . . .	$Sn O_2$	13.8
Total for . . . . .	$R R O_3$	24.9
For sesquioxide of iron . . . . .	$Fe_2 O_3$	26.8
Or,		
For oxides $2 R O$ . . . . .	$= R_2 O_2$	22.2
For binoxide of tin $3 Sn O_2$ . . . . .	$= R_3 O_3$	41.4
Total for . . . . .	$R_5 O_5$	63.6
For arseniate of lead . . . . .	$Pb_3 As_2 O_8$	65.4

Finally, the author shows, as supporting that assumption, that (as was already maintained) water is contained in solid compounds with the atomic heat of ice. The various determinations of the specific heat of ice give the atomic heat of  $H_2 O$  at 8.6 for temperatures distant from  $0^\circ$ , and at 9.1 to 9.8 at temperatures nearer  $0^\circ$ . The atomic heat has been found (to adduce again a few comparisons)

For crystallized chloride of calcium . . . . .	$Ca Cl_2 + 6 H_2 O$	75.6
For anhydrous chlorides . . . . .	$R Cl_2$	18.5
Difference for . . . . .	$6 H_2 O$	$\frac{57.1}{6} = 9.5$
For crystallized gypsum . . . . .	$Ca S O_4 + 2 H_2 O$	45.8
For anhydrous sulphates . . . . .	$R S O$	26.1
Difference for . . . . .	$2 H_2 O$	$\frac{19.7}{2} = 9.9$

The opinion that the elements enter into compounds with the atomic heats they have in the free state has been already expressed ; but the view has also been defended that the atomic heat of an element may differ in a compound from what it is in the free state, and may be different in different compounds. The author discusses the latter view, and criticises the reasons which may be adduced for it ; he comes to the result that it is not proved and is inadmissible.

As the result of all these comparisons and observations, the author arrives at the conclusion, Each element, in the solid state and at an adequate distance from its melting-point, has *one* specific or atomic heat, which may indeed somewhat vary with physical conditions (different temperature, or different density for example), but not so much as to necessitate such variations being taken into account in considering the relation in which the specific or the atomic heat stands to the atomic weight or composition. For each element it is to be assumed that it has essentially the same specific heat or atomic heat in the free state and in compounds. He then passes on to determine what atomic heats are to be assigned to the individual elements. As data for determining this he takes (1) the atomic heats which follow from determinations of the specific heat of the elements in the free, solid state ; (2) the atomic heats obtained for an element if, from the atomic heat of one of its compounds, which contains beside it only elements of known atomic heat, the atomic heats corresponding to the latter elements are subtracted ; (3) the difference found between the atomic heats of analogous compounds of an element of unknown and of an element of known atomic heat, in which case the difference is taken as being the difference between the atomic heats of these two elements. The author dwells upon the fact that in the indirect deduction of an element by (2) and (3) the result may be uncertain,—first, because the atomic heats of compounds are frequently not known with certainty, as is seen by the circumstance that analogous compounds, for which there is every reason to expect equal atomic heat, are found experimentally to exhibit considerable differences ; but secondly, because in such deductions the entire relative uncertainty, in the atomic heats for a compound and for that to be subtracted from its composition, is thrown upon a small number, viz. the residue remaining in the deduction.

The details of the considerations by which the author deduces the atomic heat of the individual elements cannot be gone into ; the results simply, which are not all attained with equal certainty, may be adduced. The author adopts the atomic heat 1·8 for C, 2·3 for H, 2·7 for B, 3·7 for Si, 4 for O, 5 for F, 5·4 for P and S, 6·4 for the other elements for which or for whose compounds the atomic heat is known in somewhat more trustworthy manner, it being left undecided in the case of the latter elements, whether (in accordance with Dulong and Petit's law) they have the same atomic heats, or whether the differences in the atomic heats cannot at present be shown with certainty.



The author gives for all compounds, whose specific heat has been investigated in a trustworthy manner, a comparison of the specific heats found experimentally with those calculated on the above assumption. The atomic heat of a compound is obtained by adding the atomic heats of the elements in it, and the specific heat by dividing this atomic heat by the atomic weight. The calculated specific heat of chloride of potassium,

K Cl, is  $\frac{6.4 + 6.4}{74.6} = 0.172$ ; of sulphide of lead, Pb S,  $\frac{6.4 + 5.4}{239} = 0.0494$ ; of

borate of potass, K B O<sub>3</sub>, it is  $\frac{6.4 + 2.7 + (2 \times 4)}{82} = 0.209$ ; of tartaric acid,

C<sub>4</sub> H<sub>6</sub> O<sub>6</sub>, it is  $\frac{(4 \times 1.8) + (6 \times 2.3) + 6 \times 4}{150} = 0.300$ .

The Table, embracing 200 compounds, shows, on the whole, a sufficient agreement between the calculated and the observed specific heats. The author remarks that a closer agreement between calculation and observation cannot be hoped for than that between the observed atomic heats of those compounds for which, from all we know at present, the same atomic heat is to be expected in conformity with Neumann's law, to which in such cases, of course, calculation corresponds. In only a few cases are differences between calculation and observation met with which exceed these limits or exceed the deviation between the results of different observers for the same substance. The author states that he is far from considering the agreement between his calculations and the experimental results as a measure of the accuracy of the latter, since the bases of calculation are too far from being trustworthy. But he hopes that his Table of atomic heats will soon acquire such corrections, and therewith greater trustworthiness, as was the case with the first Table of atomic weights. Here, the data for the Table were at first but little certain, and the differences between the calculated and observed composition of chemical compounds very considerable; but the Table was the means of corrections being introduced by which these differences were diminished.

If calculation of the specific heat does not supersede the necessity of experimental determination in the solid state, and does not give a trustworthy measure for the accuracy of such determinations, it gives a rough control for the experimental determinations, and it indicates sources of error in the experiments which without it would not have been noticed. An instance may be adduced. The author found for sesquichloride of carbon, C<sub>2</sub> Cl<sub>6</sub>, which, according to Faraday, melts at 160°, the specific heat between 20° and 50° to be 0.276 in one series of experiments, and 0.265 in another. Hence the number 0.27 might from this be taken to express the specific heat of the compound. But calculation gives  $\frac{(2 \times 1.8) + (6 \times 6.4)}{237} = 0.177$ , a very different number. A third series of

experiments with substance once more recrystallized, gave for the specific heat between 21° and 49° 0.278, confirming the previous determinations.

It might here appear doubtful whether calculation was not refuted by experiment. The discrepancy was removed by the observation that the substance is distinctly more viscous at  $50^{\circ}$  than it is at lower temperatures, and by the suspicion that it might at  $50^{\circ}$  (that is,  $100^{\circ}$  below its melting-point) already absorb some of its latent heat of vitreous fusion. This was found to be the case; two concordant series of experiments gave as the mean of the specific heat the numbers :

Between $18^{\circ}$ and $37^{\circ}$	.....	0.178
Between $18^{\circ}$ and $43^{\circ}$	.....	0.194
Between $18^{\circ}$ and $50^{\circ}$	.....	0.277

The first two numbers differ so little that it may be supposed the number found for temperatures below  $37^{\circ}$  is very near the true specific heat of this compound ; it also agrees well with the calculated number.

In the sixth part the author enters into considerations on the nature of the chemical elements.

He calls to mind the discrepancy which has prevailed, and still prevails, in reference to certain bodies, between their actual indecomposability, and the considerations, based on analogy, according to which they were held to be compound. Even after Davy had long proclaimed the elementary nature of chlorine, it was maintained that it contained oxygen. In regard both to that substance and to bromine and iodine, the view that they are peroxides of unknown elements still finds defenders. That iodine, by a direct determination of specific heat, and chlorine, by indirect deduction, are found to have an atomic heat in accordance with Dulong and Petit's law, puts out of doubt that iodine and chlorine, if compound at all, are not more so than the other elements to which this law is considered to apply.

According to Dulong and Petit's law, compounds of analogous atomic composition have approximately equal atomic heats. In general, compounds whose atom consists of a larger number of undecomposable atoms, or is of more complex constitution, have greater atomic heat. Especially in those compounds all of whose elements follow Dulong and Petit's law, is the magnitude of the atomic heat a measure of the complication, or of the degree of complication. If Dulong and Petit's law were universally valid, it might be concluded with great certainty that the so-called elements, if they are really compounds of unknown simpler substances, are compounds of the same order. It would be a remarkable result, if the art of chemical decomposition had everywhere reached its limits at such bodies as, if at all compound, have the same degree of composition. Let us imagine the simplest bodies, perhaps as yet unknown to us, the true chemical elements, to form a horizontal layer, and above them to be arranged the more simple and then the more complicated compounds; the general validity of Dulong and Petit's law would include the proof that all the elements at present assumed to be such by chemists lay in the same layer, and that, in admitting hydrogen, oxygen, sulphur, chlorine,

and the various metals as elements, chemistry has penetrated to the same depth in that range of inquiry, and has found at the same depth the limit to its advance.

But with the proof that this law is not universally true, the conclusion to which this result leads loses its authority. If we start from the elements at present assumed in chemistry, we must admit rather that the magnitude of the atomic heat of a body does not depend on the number of elementary atoms contained in a molecule, or on the complication of its composition, but on the atomic heat of the elementary atoms which enter into its composition. It is possible that a decomposable body may have the same atomic heat as an element. Chlorine might certainly be the peroxide of an unknown element which had the atomic heat of hydrogen; the atomic heat of peroxide of hydrogen,  $\text{H O}$ , in the solid state or in solid compounds, must be  $= 2 \cdot 3 + 4 = 6 \cdot 3$ , agreeing very nearly with the atomic heats of iodine, chlorine, and the elements which follow Dulong and Petit's law.

In a very great number of compounds the atomic heat gives more or less accurately a measure for the complication of the composition. And this is also the case with those compounds which, from their chemical deportment, are comparable to the undecomposed bodies. If ammonium or cyanogen had not been decomposed, or could not be by the chemical means at present available, the greater atomic heats of the compounds of these bodies, as compared with analogous potassium or chlorine compounds, and the greater atomic heats of ammonium and cyanogen obtained by indirect determination, as compared with those of potassium and chlorine, would indicate the compound nature of those so-called compound radicals. The conclusion appears legitimate, that, for the so-called elements, the directly or indirectly determined atomic heats are a measure for the complication of their composition. Carbon and hydrogen, for example, if not themselves actually simple bodies, are yet simpler compounds of unknown elements than silicium or oxygen; and still more complex are the elements which may be considered as following Dulong and Petit's law.

It may appear surprising, and even improbable, that so-called elements, which can replace each other in compounds, as for instance hydrogen and the metals, or which enter into isomorphous compounds as corresponding elements, like silicium and tin, should possess unequal atomic heats and unequal complication of composition. But this really is not more surprising than that undecomposable bodies and obviously compound bodies, hydrogen and hyponitric acid, or potassium and ammonium, should, without altering the chemical character of the compound, replace one another, or even be present in isomorphous compounds as corresponding constituents.

The author concludes his memoir with the following words:—"I have here expressed opinions, in reference to the nature of the so-called elements, which appear to depend upon allowable conclusions from well-

demonstrated principles. It is of the nature of the case, that with these opinions the certain basis of the actual, and of what can be empirically proved, is left. It must also not be forgotten that these conclusions only give some sort of clue as to which of the present undecomposable bodies are of more complicated, and which of simpler composition, and nothing as to what the simpler substances are which are contained in the more complicated. Consideration of the atomic heats may declare something as to the structure of a compound atom, but can give no information as to the qualitative nature of the simpler substances used in the construction of the compound atoms. But even if these conclusions are not free from uncertainty and imperfection, they appear to me worthy of attention in a subject which is still so shrouded in darkness as the nature of the undecomposed bodies."

- III. "On some Foraminifera from the North Atlantic and Arctic Oceans, including Davis Strait and Baffin Bay." By W. KITCHEN PARKER, F.Z.S., and PROFESSOR T. RUPERT JONES, F.G.S. Communicated by Professor HUXLEY. Received April 26, 1864.

(Abstract.)

Having received specimens of sea-bottom, by favour of friends, from Baffin Bay (soundings taken in one of Sir E. Parry's expeditions), from the Hunde Islands in Davis Strait (dredgings by Dr. P. C. Sutherland), from the coast of Norway (dredgings by Messrs. M'Andrew and Barrett), and from the whole width of the North Atlantic (soundings by Commander Dayman), the authors have been enabled to form a tolerably correct estimate of the range and respective abundance of several species of Foraminifera in the Northern seas; and the more perfectly by taking Professor Williamson's and Mr. H. B. Brady's researches in British Foraminifera as supplying the means of estimating the Foraminiferal fauna of the shallower sea-zones at the eastern end of the great "Celtic Province," and the less perfect researches of Professor Bailey on the North American coast, for the opposite, or "Virginian" end,—thus presenting for the first time the whole of a Foraminiferal fauna as a natural-history group, with its internal and external relationships.

The relative abundance or scarcity and the locations of the several species and chief varieties are shown by Tables; and their distribution in other seas (South Atlantic, Pacific, and Indian Oceans, and the Mediterranean and Red Seas) is also tabulated; and in the descriptive part of the memoir notes on their distribution, both in the recent and the fossil state, are carefully given.

In the description of the species and varieties there are observations made on those forms which have been either little understood, hitherto